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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Uddin, R., Vaut, L., & Boisen, A. (2018). *FDM-based 3D Printing of Microfluidic Discs with Multilayered Microchannels*. Abstract from 44th International conference on Micro and Nano Engineering, Copenhagen, Denmark.

FDM-based 3D Printing of Microfluidic Discs with Multilayered Microchannels

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Keywords: 3D printing, centrifugal microfluidics, multilayered microchannel, microfabrication.

Centrifugal microfluidics, unlike other lab-on-chip methods, facilitates simple, compact and low-cost instrumentation as it is free from the need of external connectors and pumping sources; as well as it facilitates effective multiplexing due to the rotational symmetry of the disc, which makes the lab-on-a-disc solution an efficient candidate for inexpensive point-of-care (POC) applications [1]. Here, we present a novel method of fused deposition modelling (FDM)-based 3D printing of microfluidic discs with multilayered microchannels which can significantly add to its POC potential as this particular fabrication method enhances the three-dimensional design freedom, is fully automated and cost-efficient.

Due to its simplicity of operation, low-cost, and user-friendliness, several studies have been performed [1] over the last decade to integrate different bioassays onto centrifugal microfluidic platforms for medical diagnostics, environmental monitoring and bioanalytical applications. However, the fabrication methods of the disc prototypes need manual intervention consisting of time-consuming steps of laser-cutting/micromilling of microchambers on polymer (e.g. PMMA) substrates and patterning microchannels on pressure sensitive adhesives (PSA) followed by manually bonding multiple layers of polymer substrates and PSA to finally form a microfluidic disc [2, 3]. The number of disc layers further increases if there are complex designs like microchannels being distributed in different layers as well as housing sacrificial valves [3] or electrodes [4] on a separate layer of the disc. FDM-based 3D printing technology for fabricating microfluidic discs has the potential to significantly decrease the number of disc layers along with effectively reducing the manual bonding procedure which would eventually lead to a minimized disc-to-disc fabrication tolerance.

Here, we demonstrate the fabrication of a microfluidic disc using FDM-based 3D printing method and demonstrate a microfluidic operation through microchannels positioned at different depths of the disc. First, the entire microfluidic disc was 3D printed using white-colored opaque polylactic acid (PLA) filament, except for the very top layer. To facilitate transparency from the top of the disc, only one PMMA layer with vent holes needed to be manually bonded on the top of the 3D printed disc through an additional PSA layer (Fig. 1) resulting in a 3-layered disc (Fig. 2a). While using the traditional approach, a total of 7 layers of PMMA and PSA are needed to fabricate the same microfluidic disc. In Fig. 1, it is illustrated that 7 layers, from the traditional approach, have been reduced to 3 layers of the disc while possessing the same functionality. Fig. 3 demonstrates the flow and subsequent mixing of two colored liquids through microchannels distributed at different depths of the disc, thus illustrating the successful fabrication of the disc with multilayered microstructures using 3D printing. In this experiment, a high centrifugation speed of 45 Hz has been used which indicates that the 3D printed disc has the potential to be used in applications requiring a high spin rate like blood plasma separation, separation of different density layers, pneumatic mixing and metering.

We have further developed a 3D printed microfluidic disc made from transparent glycol modified polyethylene terephthalate (PET-G) filament in order to make the disc fabrication process fully automated while reducing 7 disc layers to a single 3D printed layer (Fig. 2b). However, due to the material thickness and the layer-by-layer nature of the 3D printing process, the transparency of the disc is not efficient enough for clearly visualizing a microfluidic event. Thus, we are currently in the process of optimizing the material thickness, the design and print parameters in order to increase transparency, which could eventually lead to a simple, inexpensive and automated one-step process to fabricate microfluidic discs for different lab-on-disc applications.

* Dr Rokon Uddin and Lukas Vaut contributed equally to this abstract

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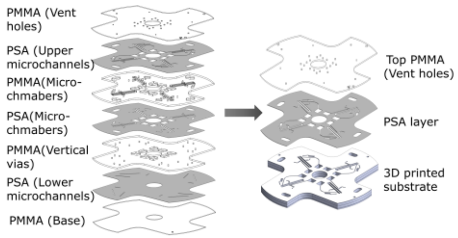

Figure 1. The left panel is the exploded view of the disc fabricated by traditional approach. The right panel represents the exploded view of the disc fabricated by 3D printing approach

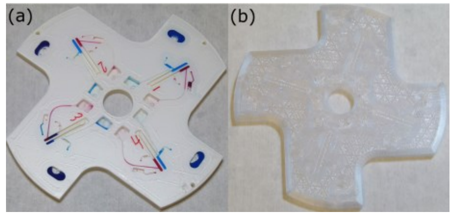

Figure 2. Photographs of the star-shaped (a) PLA-based opaque disc and (b) PET-G-based transparent disc. They were made star-shaped for reducing the required printing material and the printing time

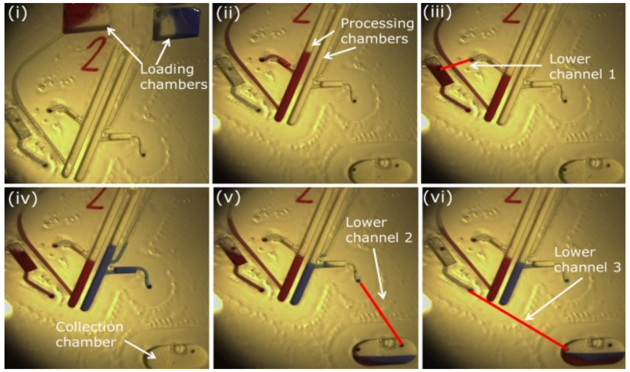

Figure 3. Sequential images of the flow and subsequent mixing of blue and red dye through microchannels at different depths of the PLA-based 3D printed disc. (i) Blue and red dye loaded into the loading chambers (ii) Red dye enters the processing chamber at 12 Hz spin rate. (iii) At same spin rate, red dye enters a 2nd chamber through lower channel-1 (microchannel positioned at a lower depth of the 3D printed disc) (iv) At 20 Hz spin rate, blue dye enters the processing chamber (v) At 30 Hz spin rate, blue dye enters the collection chamber through lower channel-2. (vi) At 45 Hz spin rate red dye enters the collection chamber through lower channel-3 and mixes with the blue dye.